Interaction Wearable Computer with Networked Virtual Environment

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Abstract. The goal of this research is to propose a technique to integrate the mobile reality system into the legacy networked virtual environment. This research composes of two essential research domains, one is networked virtual environment (NVE) and the other is mobile computing. With the proposed technique, a user can use a mobile device to join a networked virtual environment and interact with desktop users of the same virtual environment. To achieve this goal, three technical issues have to be solved including mobile networking, resource-shortage and coordinates coordination. The paper presents solutions to all of these issues. Further, a Mobility Supporting Server (MSS) is proposed to implement presented solutions into an existing networked virtual environment, called 3D virtual campus, Taiwan. The result of this experimental research enlightens the possibility of building a Multiplayer Mobile Mixed Reality (M^3R) environment in the near future.

Keywords: Networked Virtual Environment (NVE), Mobile Computing, Mobile Supporting Server, Multiplayer Mobile Mixed Reality.

1 Introduction

The Networked Virtual Environment (NVE) is the research of integrating a distributed system, network communications, and virtual reality into a graphical multi-player interactive system. In this synthetic environment, each player is embodied by a graphical representation called the avatar to convey his identity, presence, location, and activities to others.[1] Complied with the development of the computing technology,

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the research of Mixed Reality started in 1994[2]. The research of mixed reality focuses on how to integrate the digital world and the physical world into one mixed space. Depending upon the degree of integration, the mixed reality can be classified as Augmented Reality and Augmented Virtuality. As computers have become smaller and more powerful, the concept of a portable, high performance computer system for the augmented reality has become feasible and popular in the recent years[3].

Mobile Augmented Reality (MAR) is the research of the augmented reality technique on the mobile computing system. The significance of MAR is to enrich the application of the mobile computing by adding friendly interface from the augmented reality technology. With the help of the mobile computing, MAR frees the conventional augmented reality application from the desktop[4]. Mobile augmented reality allows computer-generated virtual objects to overlap with live images when the user is navigating the real world. This capability promotes the augmented reality to a more friendly and daily applications. However, one drawback of MAR is that it still isolates the user from each other. The user can only interact with the objects inside the MAR environment. He/She does not know the existence of other players. To further expand the application of MAR, the study of integrating interactive networking capability to MAR has become the trend of the recent researches[5].

However, none of these previous networked MAR researches attempts to integrate NVEs with MARs to enable MAR users to interact with conventional NVE users within a shared mixed reality space. This study refers to such an integrated environment as the Multiplayer Mobile Mixed Reality (M^3R) environment. The basic idea of M^3R is integrating NVEs with MAR to enable remote MAR users to interoperate with each others. In this study, a user who joins the virtual environment through his desktop computer is called the desktop player. Meanwhile, the mobile player is the user who uses a wearable computer or a notebook to wirelessly login the virtual environment and to interact with others while he is moving in the physical world. In the following sections, the research issues of allowing MAR user to join a conventional NVE are given first. Proposed solutions to those research issues are then followed in the next section. Finally, the implementation of a prototyping M^3R system is given in the last section.

2 Research Issues of the M^3R Environment

The goal of the M^3R environment is to enable the mobile player to join the legacy networked virtual environment and to interact with others while moving in the physical world. To enable the mobile player to interact with the desktop user, there are three important issues to be solved. First, a method is required to keep the data link between the mobile user and the desktop user alive and smooth due to the fragility of wireless network environment. Second, under the constrained and limited computing resources of the mobile device, the balance of computing load between desktop device and mobile device and the balance of transmitted data between wired and wireless networks are barely stable. Finally, because the mobile user can use the positioning device (such as Global Positional System receiver) to provide his location information to the virtual world, consequently, if the result of coordinated data from Geographical coordinate system of the physical space could be matched with position data from Cartesian coordinate system adopted by the virtual world or not would affect the interaction between mobile and desktop players.

The above issues can broadly classified into three categories. One is the stability and bandwidth problem of the mobile network. The second issue is the limited computation resources of the mobile device. The last one is the data correlation between the Geographical coordinate system and the Cartesian coordinate system. Upper part of Figure 1 depicts these three issues and their sub-problems.

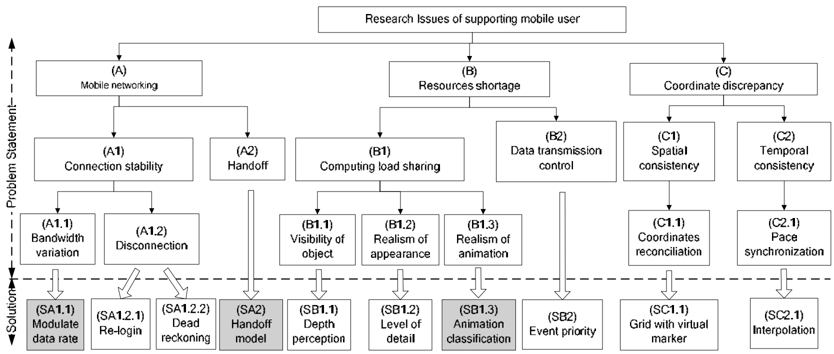

Fig. 1. Hierarchies of research issues and proposed approach of M^3R environment

2.1 Mobile Networking (Box Labeled A)

The mobile user joins virtual shared space through the wireless network. Hence, the signal stability of wireless network will affect the interaction between the mobile players and desktop players. The advantage of wireless network is to allow the mobile device to compute while its carrier is moving in the open coverage of access point (AP). The research of [6] pointed out the fragile wireless signal induce the connection stability and handoff problem. The connection stability issue further includes disconnection and bandwidth variability problems. The instability of signal affected by surrounding environment and the moving speed of the carrier would lead to the disconnection problem. The bandwidth variability is often related to signal strength between AP and the mobile device. The handoff problem occurs when the mobile player moving away from the coverage of one AP and entering another coverage range. The choice of wireless network includes GPRS, 3G, WiMAX and WiFi, etc. and each of them has different factors to causes the above mobile networking issues. Hence, this study is not focus on any specific wireless network but explores the logical linking problem only. That is, this study targets on how to keep logical link between the mobile player and the server alive while the signal strength still exists within an acceptable threshold.

2.2 Resource Shortage (Box Labeled B)

This issue focuses on the performance problem caused by the limitation of the mobile device. The mobile device is always designed with the limitation of display capability, power consumption and CPU, and these constraints will significantly affect the computing performance. To solve this problem, computing load of the mobile device has to be reduced and shared by others. Further, the wireless network is the only way for the mobile device communicates with the server, the variation of the bandwidth can not guarantee that interactive message can be transmitted between the mobile device and the server in time. This situation, in turn, will influence the interaction among players in the same virtual world. These limitations of the mobile device will consequently affect the realism of interaction when the mobile device is interactively communicated with other computing devices. Hence, the resource shortage issue can be further classified into two sub-problems: computing load sharing and data transmission control.

Because, other than exchange messages with other player, the majority work of the mobile device is to display 3D information, the rendering becomes the major load of the mobile device. Therefore, to solve the loading sharing problem, graphic render related computing works have to be studied such as the visibility of objects, the realism of object appearance and the realism of object animation. The visibility problem is aimed to limit the visible of distant objects. Whereas the realism of appearance and animation are focus on reduce the complexity of appearance and animation, respectively, of the distant visible objects.

2.3 Coordinate Discrepancy (Box Labeled C)

Since the mobile player uses the position sensing device (such as GPS) to navigate the virtual world and to animate his remote avatar, this location information has to be converted into the position data recognizable by the virtual world. However, since the data from GPS is expressed in Geographical coordinate system whereas the virtual world uses Cartesian coordinate system, this conversion may cause spatial and temporal inconsistency between the mobile player and the desktop player. That is, as long as the mobile player is moving in the physical world, the difference of these two coordinate systems may corrupt the causal order relationships of events within the shared virtual world. Hence, coordination positional data and events between these two coordinate systems will significantly affect the realism of interaction. Further, the moving speed of the mobile player can be misinterpreted by the Server which, in turns, causes the temporal relation error as well as interaction among players.

3 Proposed Solutions

The solutions for the M^3R interaction issues of the previous section comprise the research domains of networking, graphics and coordinates studies. Each issue and sub-problem had already been discussed and proposed solution from its perspective domain. Each solution has its pro and con. This study studies various solutions from their respective domains and recommends the most suitable solution from the view point of the overall performance. Lower part of Figure 1 depicts the proposed solutions of corresponding problems.

3.1 Solutions for Mobile Networking (Box Labeled A)

Since the bandwidth variation problem is deeply affected by the deployed underline wireless network such as GPRS, 3G, WiMAX and WiFi, etc., this study will not put focus on this problem. For the disconnection problem, a simple yet effective solution is to periodically detect the connection status of the mobile player. If the duration of disconnection is within a given threshold, the server can simply adjust message update rate of the mobile player to avoid wasting of bandwidth usage. The most well-known mechanism for this solution is the heartbeat function from DIS[7]. According to the heartbeat mechanism, the mobile player will periodically send a connecting message to the server. If this heartbeat sequence is interrupted, the server will then be aware the instability of the wireless network. If this disconnection is longer than a given threshold, the server then kick out the mobile player for him to re-login later. Otherwise, the server can redeem the missing data by the dead reckoning algorithm[8] as defined in DIS protocol. That is, the server can use the past history of the mobile player to predict his movement and forward this prediction to other players. Notice that the proper threshold is related to the frequency of re-logins. Based on the instable wireless signal, a frequent re-login situation can easily flood the wireless bandwidth with duplicated messages on the mobile host.

The last problem of the mobile networking is the handoff problem. The solutions to this problem may range from the physical layer to the application layer. For the M^3R environment, research in [9] points out that the soft handoff model is a reasonable approach. However, the actual solution is decided by the wireless network technique that is used. Hence, it is not fully discussed in this paper.

3.2 Solutions for Resource Shortage (Box Labeled B)

The mobile device always has inferior computing resource than the desktop device. This inferior computing resource can be categorized into two types: the computation power of the mobile device itself and the communication resource to the outside world. The resource shortage service attempts to solve these problems based upon the characteristics of networked virtual environment. The inferior computation power could be solved by sharing some of the computing load on the mobile device to the server site. As to the limitation of the communication resource, it can be solved by controlling the data flow between the server and the mobile device to maintain their interaction.

The rationale of computation sharing can be derived from the limitation of the human visual perception. For example, when the human being is moving, his eyesight to a distant object tends to be less perceptible. Hence, the depth perception[10] technique can be adopted to reduce the number of the rendered objects to solve the problem of visibility of objects. According to the depth perception technique, if the server site can use the status of a mobile player to compute remote objects that are within his field of view (FOV) [11] and forward this information to the player, the computing load of that mobile device will then be significantly saved.

Once a distant object is within the perception distance of a player, further load sharing can be achieved by reducing the realism of appearance and animation. For the realism of appearance issue, the level-of-detail(LOD)[12] technique is a conventional approach to render an object with different resolution according to its distance to the viewer. If an object far away from a viewer, less polygonal information is required for the viewer to identify that object which, in turns, implies less computation to be needed. However, the decision of model resolution of an object to a viewer can be computation intensive as the number of objects within a virtual environment is increased. Hence, if the server site can also forward the resolution information of a remote object when passing its status information to the mobile device, the computing load of the mobile device can then be saved. In other words, the server site pre-computes the resolution of a remote object before forwarding its status information to the mobile player. The computing load of the mobile device is then reduced by simply rendering objects according to its received resolution information.

To further adapt to the bandwidth variance during the interaction, the data priority [13] approach is adopted to sort transmitted message to the mobile device. According to [13], messages flow within the virtual environment are prioritized according to their importance to the interaction. Low priority event messages can be preempted by high priority event message. If a low priority event message is preempted over a predefined period, it will be then regarded as old event to be discarded away. With this approach, the data transmission control issue is the resolved by requesting the server to send message to the mobile player based upon the priority of that message. Meanwhile, the mobile player will reduce the frequency of message transmission when the bandwidth is reduced.

3.3 Solutions for Coordinate Discrepancy (Box Labeled C)

The differences in the coordinate systems used by the virtual world and the physical world can cause both the spatial and temporal inconsistency problems between the mobile player and the desktop player. To solve the spatial inconsistency problem, the coordinate correlation between the physical world and the virtual world needs to be computed beforehand. However, there is no direct translation from a point in the Geographical coordinate system to its corresponding coordinate in the Cartesian coordinate system. To solve this problem, a third coordinate system, called the Earth-Centered, Earth-Fixed(ECEF) [14] is developed. ECEF coordinate system is used as the mediator. That is, GPS data are first translated from the Geographical coordinate system into data in the ECEF coordinate system, and then the Cartesian coordinate system. This pipeline of translation consists of a sequence of complex matrix manipulation which is not suitable for the computation requirement for NVE. Especially when the client device is mobile device, the complexity of computation may

Fig. 2. The geographic markers(left) and the virtual makers(right)

not be acceptable. To solve this coordinate reconciliation problem, a simple yet effective translation is required. First, the Cartesian coordinate system is manually assigned to the virtual world when the virtual world is designed. Each object within the virtual world is then placed corresponding to this Cartesian coordinate system. Second, fixed positions within the virtual world are carefully chosen as the virtual markers. In the physical world, the geographic markers that are corresponding to those virtual survey markers, respectively, are then computed, as illustrated in Figure 2. In other words, each geographic marker is a physical location that is mapped to the virtual marker. The geometric relationship between the geographic marker and the virtual survey marker is then calculated. This relationship becomes the equation to transfer the geographic position in the physical world to a coordinate data in the virtual world and vice versa.

In addition, the proportional scale between the virtual world and the physical world will cause a temporal inconsistency problem between the mobile player and the desktop player. For example, when a mobile player is walking across the road, his motion may be misinterpreted by a desktop computer as a fly motion due to the scaling difference in the input data. "A shared sense of presence" is one of five common features for the networked virtual environment[1]. This feature is achieved by allowing each player to control the motion of an avatar inside such a shared space. For a desktop player, the mouse and keyboard are two legacy input devices to support navigation and interaction within the virtual environment. On the other hand, since the mobile player uses the GPS data to navigate the virtual world, the GPS receiver becomes an input device to control the motion of his remote avatar. That is, when the mobile player is walking in the physical world, his location is tracked by the location sensor and transmitted to other players through the server. From the viewpoint of the desktop player, the mobile player is navigating the virtual world by his own motion. Hence, the Geographical coordinate from the GPS receiver and orientation from the electronic compass needs to be correctly mapped to position and direction inside the virtual world. This mapping is achieved by first computing the geometrical ratio among given position and geographic markers that were set when the virtual world was designed. The Cartesian coordinate of this position is then derived from computed geometrical ratio with respect to the virtual markers. This approach allows fast translation between the Geographical coordinate and Cartesian coordinate with an acceptable spatial inconsistency. This technique also tolerates different moving speeds when the mobile is walking in the real world. Only when the walking speed is below a predefined value, the accurate Cartesian coordinate will be actually computed.

4 Implementation

Other than the proposed solutions of the interaction issues, the implementation approach will also affect the performance of M^3R environment. The most straightforward implementation is to allow the mobile device to communicate with the multi-user server directly and to implement proposed solution on the multi-user server. However, this type of implementation will overload the server and, hence, decrease the performance of M^3R environment. To avoid this problem, as illustrated in Figure 3, a mediate server called Mobile Support Server (MSS) was designed to realize the proposed solutions. The MSS play the role of a data mediator between the multi-user server and the mobile player. For multi-user server, MSS is a desktop player that controls multiple avatars inside the virtual world. On the other hand, the mobile player treats the MSS as a special-purpose server that shares some of its computation load.

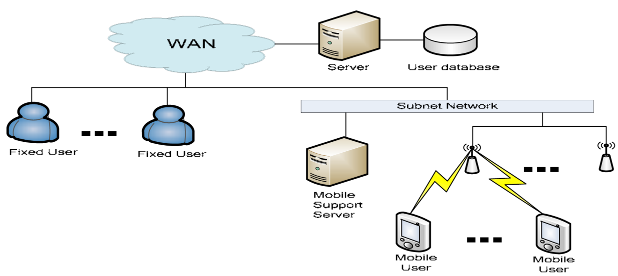

Fig. 3. The architecture of M^3R environment

The Mobile Support Server (MSS) is implemented on the Windows XP platform. To further verify the validity of the proposed solutions, the MSS is realized on the existing networked virtual environment called 3D virtual campus[15]. The 3D virtual campus is a networked virtual environment of National Taipei University (NTPU), Taiwan. By adding MSS, both the mobile players and desktop players are allowed to join this 3D campus environment. The position of the mobile player is derived by the GPS receiver. The mobile device, i.e. a wearable computer or a notebook, will translate and transmit its received GPS data to the server. The server then forwards the received data to other players for them to remote render his avatar. Hence, the 3D campus project allows more vivid interactive experiences when the user is navigating this overlapped virtual and physical worlds. The movement of the mobile player changes with the virtual reality picture as Figure 4 is the snapshot of the mobile devices.

Fig. 4. The snapshot of the mobile device

Skype [16] capability is further embedded in the 3D virtual campus to enable live chatting among players. When a user wants to chat with another player on the user list, he can directly click that player's name. The system will then launch the Skype software to connect to that specific player. For example, if the user "sennin32" wants to voice chat with, says, "annheilong", he can click the receiver's name, "sennin32", on the right sub-window or on top of the avatar. As shown in Figure 5, a calling notification will pop-up on the receiver's browser. The receiver can decide whether to accept or deny this call by clicking buttons on the pop-up window.

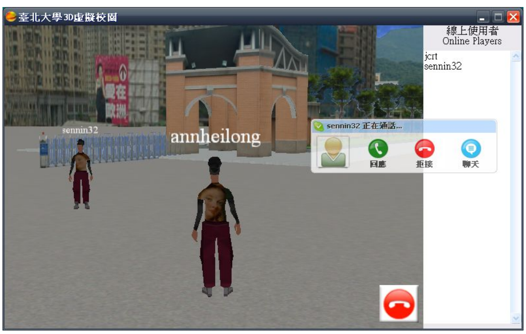

Fig. 5. Live chatting through Skype software

5 Conclusion and Future Work

This paper studies the techniques to integrate mobile computing into the networked virtual environment. The integrated environment is referred as Multiplayer Mobile Mixed Reality (M^3R) environment and it enables the user to wear a mobile device to interact with the conventional desktop player in the shared virtual space. This paper fully discusses technical issues to design such a networked mixed reality environment. The first issue is to keep steady connection between the mobile device and the server under the instable wireless environment. The second issue is to maintain interaction performance under the constraint of the limited computing resource of the mobile device. The last issue is to solve the data inconsistency problem caused by the difference of two coordinate systems which are the Geographic coordinate system and the Cartesian coordinate system.

Further, the solutions to the above research issues are presented along with the proposed implementation approach. To fully support the mobile player, a Mobile Support Server(MSS) is designed for the traditional NVE as the data mediator between the mobile player and desktop player. In essence, the MSS is the mechanism to share parts of the computation of the mobile device when the mobile player is interacting with the mixed reality environment. Finally, architecture of a NVE with MSS is also presented in this paper.

Although the implementation of the 3D virtual campus project successfully verifies the effectiveness of MSS to support a M^3R environment, more research issues are exposed for further studies. For example, from the prior experiences, notebooks are proved to be unsuitable for mobile users to operate in moving. The ultimate goal of the mobile device is an optical see-through mobile augmented reality system running on a wearable computer. In addition, the orientation of the mobile player and, hence, the corresponding display of the virtual world is another important issue that requires further investigate. In an M^3R system, the digital compass is used to detect the rotation of the mobile player. The digital compass has a well known inaccurate and unstable problem. Consequently, other auxiliary orientation sensor requires further exploration. Currently, the research of using the optical flow technology to detect the mobile player's rotation is under study. Finally, the performance of MSS is another important topic that deserves further probe.

References

1. Singhal, S.K., Zyda, M.J.: Networked Virtual Environments Design and Implementation. Addison Wesley, Reading (1999)
2. Milgram, P., Kishino, F.: A Taxonomy of Mixed Reality Visual Displays. IEICE Transactions on Information Systems E77-D (12), 1321–1329 (1994)
3. Rosenblum, L.: Virtual and Augmented Reality 2020. IEEE Computer Graphics and Applications 20(1), 38–39 (2000)
4. Feiner, S., MacIntyre, B., Höllerer, T., Webster, T.: A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. In: Proc. ISWC 1997 (First IEEE Int. Symp. on Wearable Computers), Cambridge, MA, October 13-14, Also in Personal Technologies, pp. 208–217 (1997)
5. Kortuem, G., Bauer, M., Heiber, T., Segall, Z.: NETMAN: The Design of a Collaborative Wearable Computer System. Mobile Networks and Applications 4(1), 49–58 (1999)
6. Forman, G.H., Zahorjan, J.: The challenges of mobile computing. IEEE Computer 27(4), 38–47 (1994)
7. Distributed Interactive Simulation, IEEE Standard 1278.1a, `http://ieeexplore.ieee.org/ISOL/standardstoc.jsp?punumber=5896`
8. Singhal, S.K.: Effective remote modeling in large-scale distributed simulation and visualization environments. Stanford University, Stanford, CA. PhD thesis (1996)

9. Huang, J.Y., Tsai, C.H.: A Wearable Computing Environment For The Security of A Large-Scale Factory. In: Jacko, J.A. (ed.) HCI 2007. LNCS, vol. 4551, pp. 1113–1122. Springer, Heidelberg (2007)
10. Wann, J.P., Rushton, S.K., Mon-Williams, M.: Natural problems for stereoscopic depth perception in virtual environments. Vision Research 19, 2731–2736 (1995)
11. Kolb, H., Fernandez, E., Nelson, R.: The Organization of the Retina and Visual System, http://webvision.med.utah.edu/index.html
12. Clark, J.: Hierarchical geometric models for visible surface algorithms. Communication of the ACM 19(10), 547–554 (1976)
13. Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments: A presence questionnaire. Presence: Teleoperators and Virtual Environments 7, 225–240 (1998)
14. ECEF datum transformation, http://www.satsleuth.com/GPS_ECEF_Datum_transformation.htm
15. Huang, J.Y., Tung, M.C., Keh, H.C., Wu, J.J., Lee, K.H., Tsai, C.H.: A 3D Campus on the Internet – A Networked Mixed Reality Environment. The Transactions on Edutainment (to appeared, 2009)
16. Prasolova-Førland, E., Sourin, A., Sourina, O.: Cybercampuses: Design Issues and Future Directions. The Visual Computer 22(12), 1015–1028 (2006)